Robot-mediated joint attention in children with autism

A case study in robot-human interaction*

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Interactive robots are used increasingly not only in entertainment and service robotics, but also in rehabilitation, therapy and education. The work presented in this paper is part of the Aurora project, rooted in assistive technology and robot-human interaction research. Our primary aim is to study if robots can potentially be used as therapeutically or educationally useful 'toys'. In this paper we outline the aims of the project that this study belongs to, as well as the specific qualitative contextual perspective that is being used. We then provide an in-depth evaluation, in part using Conversation Analysis (CA), of segments of trials where three children with autism interacted with a robot as well as an adult. We focus our analysis primarily on joint attention which plays a fundamental role in human development and social understanding. Joint attention skills of children with autism have been studied extensively in autism research and therefore this behaviour provides a relevant focus for our study. In the setting used, joint attention emerges from natural and spontaneous interactions between a child and an adult. We present the data in the form of transcripts and photo stills. The examples were selected from extensive video footage for illustrative purposes, i.e. demonstrating how children with autism can respond to the changing behaviour of their co-participant, i.e. the experimenter. Furthermore, our data shows that the robot provides a salient object, or mediator for joint attention. The paper concludes with a discussion of implications of this work in the context of further studies with robots and children with autism within the Aurora project, as well as the potential contribution of robots to research into the nature of autism.

Interaction Studies 5:2 (2004), **161–198.**
ISSN 1572–0373 / E-ISSN 1572–0381

Keywords: Robotics, autism, learning, therapy, Conversation Analysis, toys, joint attention

1. Introduction

This work is part of the Aurora project which investigates the possible use of robots in the therapy and education of children with autism (Aurora, 2004). Children with autism have difficulties in social interaction, communication and imagination. The project focuses on the development of new interactive robotic systems that encourage basic communication and social interaction skills. We collaborate with several schools where we run trials in which children play with different types of robots, including mobile robots and a humanoid robot that can engage children in simple interactive activities, e.g. imitation and turn-taking games.

1.1 Autism

Autism here refers to the term Autistic Spectrum Disorders which comprises a range of manifestations of a disorder that can occur to different degrees and in a variety of forms (Jordan, 1999). Autism is a lifelong developmental disability, often accompanied by learning disabilities, that affects the way a person communicates and relates to people around them. The exact cause or causes of autism is/are still unknown. For detailed diagnostic criteria the reader is referred to DSM-IV, the Diagnostic and Statistical Manual of Mental Disorders, American Psychiatric Association (1995). For the purpose of this paper we list the main impairments that are characteristic of people with autism, provided by The National Autistic Society (NAS, 2004):

a. impaired social interaction — the inability to relate to others in meaningful ways, difficulty in forming social relationships, the inability to understand others' intentions, feelings and mental states.
b. impaired social communication — difficulties with verbal and non verbal communication e.g difficulties in understanding gesture and facial expressions, difficulty in understanding metaphors etc.
c. impaired imagination — difficulty in the development of play, and having limited range of imaginative activities.

In addition, people with autism usually exhibit little reciprocal use of eye-contact and rarely get engaged in interactive games. They show a tendency towards repetitive behaviour patterns and resistance to any change in routine. The data that we present in this paper is selected from trials that aimed at encouraging turn-taking and imitative behaviour involving children with autism interacting with a small humanoid robot.[1] In these trials we found instances of joint attention between the children and an adult present. These examples of joint attention were then analysed in depth using Conversation Analysis.

1.2 Joint attention in autism

The investigation of joint attention skills in children with autism is an extensively studied topic in autism research. A full review of the literature would go beyond the scope of this paper. However, in this section we discuss selected references relevant to the present work.

Children's use of non-verbal interactive resources like gaze and proto-declarative pointing, to share their attention to an object or third person with others, are referred to as *joint attentional skills*. These triadic referencing activities emerge in typically developing children between about 9 and 18 months of age. Research in the last few decades has indicated that young children with autism are impaired in their ability to initiate these indicating activities (e.g. Curcio, 1978; Mundy & Crowson, 1997; Sigman et al., 1986; Leekam, 2003). This is reflected in the notion of a 'joint attention deficit', described in the Diagnostic & Statistical Manual of Mental Disorders (DSM) as "a lack of spontaneous seeking to share enjoyment, interests or achievements with other people (e.g. by a lack of showing, bringing or pointing out objects of interest)" (American Psychiatric Association, 1995, p.72). There has been considerable debate about the significance of this 'deficit' in relation to social reciprocity in autism, and its links to other theories of social deficit (Mundy & Sigman, 1989). More recently, Siller & Sigman note that in autism "nonverbal communication is characterised by a lack of joint attention" (2002, p.77).

Other research has suggested that children with autism (particularly those with a low verbal mental age) are impaired in *following* the gaze and head direction activities of others (Leekam et al., 1998). At the same time it has been suggested that older and verbally higher functioning children with autism are better (though still somewhat impaired) in initiating and following joint attention (Leekam et al., 2000; Travis et al., 2001). Even studies who suggest group differences in joint attention between children with autism and control groups show that joint attention behaviour is indeed not completely absent in children with autism (cf. Carpenter et al., 2002). The occurrence of joint attention skills in children with autism is a fundamental starting point for our studies. It indicates future research and provides grounds for possible future design of interventions that elicit their use. At this stage however, we focus on the particular qualities, organization and delivery of referencing behaviour by analysing in great detail occurences of joint attention that emerge spontaneously in natural interactions betweeen an adult and a child with autism, in a playful context where a robotic 'toy' serves as a focus of attention, a salient object in the environment that mediates the interactions.

The qualitative approach adopted in this paper (Conversation Analysis) enables us to make sense of autistic children's gaze initiating and gaze following behaviour with reference to what other participants (an adult and a robot in this case) are doing at the time. By focussing on the co-occurring activity of child, adult and robot we can explore how children with autism initiate and orientate to joint attention bids in interactions involving a robotic device.

1.3 The analytic perspective

The analytic perspective used in this paper is that of Conversation Analysis (CA). CA is a field of empirical research (emerging principally from the work of Harvey Sacks, Sacks, Schegloff & Jefferson, 1974, Sacks 1992) which has provided a framework for the detailed scrutiny of the action mutually accomplished by participants in sequences of interaction (ten Have, 2004). It focuses upon what is being done at any given moment in any form of interaction. This is achieved by considering the participant's responses to and shaping of each other's talk. In this way all interactional activities (vocal and non-vocal) can be understood as being responded or orientated to in terms of their *conditional relevance* (Schegloff, 1968). That is, any interactional move creates an interpretative environment through which participants make sense of any action (vocal or non-vocal) which occurs next. Conversation analysts monitor how participants treat each other's actions within the sequence of interactional events in which they are placed and how such actions shape the context for subsequent interaction. In doing so, conversation analysts emphasise the sequential placement of the participants' actions; for example, where in an interaction sequence a gaze at a co-participant occurs and what kind of action it may be undertaking or projecting, given the specifics of its placement and in the light of the co-participant's treatment of it.[2] A key finding of CA research is that interaction (particularly in its core everyday form) is a locally managed activity, and that participants are sensitive to their co-participants in the design of their talk

(Sacks et al., 1974). Here, the term *recipient design* is used in a very specific way to highlight the observation that speakers design features of their conversations, e.g. the allocation of 'turns', by orienting towards the other recipients. This analysis of everday talk has been expanded to include gesture and body movement as examples of the ways in which co-participants can skilfully orientate to each other (Goodwin, 2003a). Heath & Hindmarsch (2002) and Goodwin (2003c) exemplify that far from being restricted to just 'conversation' – conversation analysis is an analytic framework that can be fruitfully applied to all aspects of interaction (vocalisations, prosody, gesture gaze and body movement). In addition to providing a framework for considering both vocal and non-vocal activity Heath & Hindmarsch argue that conversation analysis (and the closely related field of ethnomethodology) provides a framework in which *material features of the environment* can be considered.[3] Such features are not *presumed* to be important but are instead investigated in terms of how they are made relevant in and through interaction. A basic finding of CA is that skilful participants design their actions (talk, body movement, gaze, gesture etc) such that they attend to the activities undertaken (or projected as to be undertaken) by their co-participant(s). These findings from previous CA research are of direct relevance to the study of interaction involving children with autism and a robot. CA provides a framework which encourages the detailed transcription and analysis of all vocal and non-vocal activities that are available and potentially relevant to the participants. These include the movements and sounds of a minimally vocal robot which might be relevant and influential to the action of other participants. Monitoring precisely where in the interaction sequence particular sorts of actions occur enables us to consider what sorts of actions on the part of robot, adult or child might give rise to action (or behaviour) that is of interest to us. CA may help to understand more precisely both the deficits in social interaction skills that children with autism might have and the competencies of children with autism in skills that might otherwise go unnoticed. In this paper we demonstrate the use of CA in analysing interactions in a social setting involving a robot, an experimenter, and a child with autism. Our particular analysis focuses on joint attention behaviours.

In contrast to other research approaches used to investigate autism, CA does not use control groups.[4] Instead, if we find that an autistic child uses gaze to specify a gesture in a certain way then the relevant point of comparison is how typically developing children (and other 'competent' communicators) might use gaze in *related interactional circumstances* rather than in a similar trial in which quite different gaze and gestural activities will emerge. Therefore whilst space precludes as extensive a comparison the current paper illustrates the use of comparative data in specifying the sorts of interactional competencies that are revealed in our data.

1.4 Computers and robot technology in autism therapy and education

Literature suggests that people with autism feel comfortable in predictable environments, and enjoy interacting with computers, e.g. (Colby & Smith, 1971; Powell, 1996; Moore, 1998). Murray (1997) noted that the attention of people with autism tends to be fixed on isolated objects apart from the surrounding area. She argued that computers are the ideal resource to break into this world because they allow to join the individual's *attention tunnel* which focuses on the screen and thus external events can be ignored more easily. She added that the use of computers in the education and therapy of people with autism can help develop self-awareness, increase self-esteem and be an aid to effective communication as it can motivate the individual to speak, read or to share their achievements. Hershkowitz also made a strong case of the usage of computers in therapy and education (Hershkowitz, 1997; Hershkowitz, 2000). She found that the implementation of computer based learning provides a very effective method for teaching language and academic skills to children with autism, and helping adults to become independent.

In recent years there have been many examples of using interactive systems in the therapy or education of people with autism, cf. review in (Dautenhahn & Werry, in press). Such systems include virtual reality or virtual environments (e.g. Strickland, 1996; Parsons et al., 2000). Therapists and teachers are increasingly using virtual reality tools to teach social and life skills (e.g. recognising emotions, crossing the road). The regulated computer environment that virtual reality can offer is used to help people with autism rehearse problematic real-life situations and learn how to better cope with the real world (Strickland, 1998).

For decades, the use of robots in education has been an active area of research (e.g. Papert, 1980; Druin & Hendler, 2000).[5] In early work in the 70s, Weir and Emanuel (1976) investigated the use of a remotely-controlled mobile robot as a therapeutic or educational device for one child with autism and reported positive effects of a LOGO turtle on a seven year old boy. More recently, Michaud and Théberge-Turnel studied the use of mobile robotic toys in helping children with autism develop social skills. They explored various robotic designs, each with particular characteristics, that can best engage the children, and presented playful interactions of children with autism with robots in variety of designs e.g, an elephant, a spherical robotic 'ball', a robot with arms and a tail, and other designs (Michaud & Théberge-Turnel, 2002). The work focussed on exploring the design space of robots that can facilitate interactions with children. As such, results of interactions of children with autism and robots have been presented in a narrative account, without any systematic evaluations (qualitative or quantitative) that are central to our work. Other work that studies the use of robots in playful interactions with children with autism was carried out by Wada et al. (2002) who developed a seal pet robot as an assistive tool in rehabilitation and robot assisted activity. In this work, too, very little details have been documented about the particular role of the robot, e.g. what types of robotic behaviours have been beneficial to the child, and what types of therapeutically relevant behaviours were targeted. Different to the above mentioned approaches, our work focusses on encouraging specific behaviours in children with autism, namely turn-taking, imitation and joint-attention.

1.5 Robots in the Aurora project

As people's social behaviour can be very subtle and widely unpredictable, the use of robots allows for a simplified, safe, predictable and reliable environment where the complexity of interaction can be controlled and gradually increased. Ferrara and Hill (1980) reported that children with autism prefer simple designs and a predictable environment for their interaction with toys. They concluded that these are more appropriate starting points for therapeutic intervention where the complexity of the therapeutic toys can be slowly increased.

Part of our investigation is how we can encourage social interaction skills using simple imitation and turn-taking games. We also are investigating how the robots can be used as objects of shared attention, encouraging interaction with peers and adults. The Aurora project uses mobile and humanoid robots e.g. (Werry et al., 2001; Salter et al., 2004; Dautenhahn, 1999; Dautenhahn and Billard, 2002). Werry et al. (2001) illustrated the ability of a mobile robot to provide a focus of attention, and shared attention, in trials with pairs of children with autism. In one instance one child learnt a new interaction with the robot from the experimenter, and later taught this skill to a second child. In the same pair trials, the robot's role as a mediator became apparent in child-teacher interactions, child-investigator interactions and child-child interactions. In other work we identified the need for robots to detect different interaction styles and to adapt to individual behaviour of children, following Ferrara and Hill's (1980) suggestion to gradually change the complexity of toys for children with autism, cf. preliminary work with typically developing children reported in (Salter et al., 2004). A precursor of the work presented in this paper is the study conducted by Dautenhahn and Billard (2002) who reported on a first set of trials with 14 children with autism interacting with a humanoid robotic doll. Lessons learnt from that study have led to a recent longitudinal study (Robins et al., 2004), inspired by therapeutic issues, using the same humanoid robot. The data that we present in this paper derives from this longitudinal study.

2. Current work

This paper reports additional findings based on our recent longitudinal study (Robins et al., 2004). In that study four children with autism were repeatedly exposed to a humanoid robot over a period of several months, with the aim of encouraging imitation and social interaction skills. Different behavioural criteria (including Eye Gaze, Touch, and Imitation) were evaluated, using mainly observational, statistical analysis techniques based on the video data of the interactions. Observational analysis of video material, with subsequent statistical evaluation, is a widespread method in ethology (e.g. Lehner, 1996) as well as psychology (e.g. Tardiff et al., 1995). Similar techniques for evaluating robot-human interactions have also become established in robotics (e.g. Kanda et al., 2003) where the frequencies and temporal structure of behaviours are a main focus. On the other hand, rather than pursuing a statistical approach techniques such as Conversation Analysis (CA) can provide in depth information on *behaviour in context* which is important as a means to reveal the *meaning* of behaviour in a social context. A first example of applying this approach in the Aurora project, to analyse interactions of children with autism with a robot is presented in (Dautenhahn et al., 2002), also compare Dickerson et al. (in press).

It is important to note that the project is not committed to any particular theory on the nature of autism.[6] However, this paper gives an example of how the data we collect on child-robot-adult interactions, and the subsequent analysis using CA, highlights details of the communicative and social *competencies* of children with autism, in particular, providing in-depth analysis of illustrative examples where children with autism can respond to the changing behaviour of their co-participant.

3. The research focus

This paper presents a comprehensive qualitative analysis of some of those segments of the trials where the children showed interaction skills and communicative competence in their interaction with an adult in the presence of a robot (the object of shared attention). Note, that this analysis does not rely on any pre-specified definition of joint attention which is necessary for cases where the number of occurrence of joint attention behaviour is counted. Most importantly, we focus on the co-participant's actions, which we consider crucial in understanding the joint attention activity of a child. In other words, where the adult is gazing seems to greatly impact on the particular sequence of gaze and pointing activity that the child will exhibit. This particular research focus is consistent with Prizant et al. (2000) who indicate the importance of considering what they call 'transactional supports', such as co-participant's actions, which is precisely the focus of our current paper. Likewise, psychologists have a long tradition of microanalyses. The developmental pragmatics literature and its forerunners (Condon & Ogston, 1967; Condon & Sander, 1974; Condon, 197[illegible]) can be regarded as stepping stones towards the current study in its focus on a range of children's interactional accomplishments, often in naturalistic settings, and sometimes with reference to the co-participant's actions. Similarly, McArthur & Adamson (1996) acknowledge the role of the co-participant in the production of joint attention activity (as well as having a more open definition of referencing activity). Our current paper develops the attention to the actions of the co-participant by exploring the sequential placement of joint attention related activities on the part of the autistic child and exploring in detail how these actions are made relevant by the actions of the co-participant (e.g. where they are gazing and what they are saying or doing). It is this responsiveness to interactional contingencies, hinted at in these earlier papers, which becomes the key focus in our current paper.

4. The trials

4.1 The approach

We designed our trials to take place over several months. On the one hand we wanted to minimize the anxiety and distress the children with autism might experience, caused by a change of routine, being in a novel situation with a new and unusual toy (the robot), and a new person (the investigator). On the other hand we wanted to allow enough time for the children to use any interaction skills they might have (e.g. eye-contact, turn-taking, imitation), in a reassuring environment, where the predictability and repetitive behaviour of the robot is a comforting factor. Furthermore, we intended to allow enough time and opportunity for the children to possibly improve their social interaction skills by attempting imitation and turn-taking games with the robot while slowly increasing the unpredictability of the robot's actions.

Overall, this approach has been designed to allow the children to have unconstrained interaction with the robot with a high degree of freedom, on their own terms to begin with (providing it is safe for the child and safe for the robot), and to build a foundation for further possible interactions with peers and adults using the robot as a mediator (Werry et al., 2001).

4.2 The set up

The trials took place in Bentfield Primary school in Essex, UK. This is a mainstream school with an Enhanced Provision unit that caters for nine pupils with various learning difficulties and physical disabilities. This includes a small group of children with autism which the first author of this paper is working with on a regular basis.

The trials were conducted in a room familiar to the children, often used for various other activities. The room was approximately 5.5m x 4.5m, with a carpeted floor and had one door and several windows overlooking the school playground. The robot was connected to a laptop and placed on a table against the wall at one side of the room. Two stationary video cameras were placed in the room, one at the side near the wall pointing to the front of the robot, capturing the children when approaching the robot, and the other placed behind the robot to try and capture the facial expressions of the children as they interacted with the robot in close proximity. We felt that having manned cameras (with yet more adult strangers in the room) would be too intrusive and would cause additional stress to the children. However, despite having two cameras in most of the trials, there were periods of time when the children moved outside the range of the cameras, as the nature of the trials gave them the freedom to move around in the large room.

4.3 The robot

The robot used in these trials was Robota — a 45 cm high, humanoid robotic doll (Billard, 2003). The main body of the doll contains the electronic boards and the motors that drive the arms, legs and head giving 1 DOF to each. The arms, legs and head of the robot are plastic components of a commercially available doll. The robot was connected through a serial link to a laptop.

In the trials, the robot had two different appearences — one of a 'pretty girl doll' and the other more 'robot like' with plain clothing and a featureless head (see Figure 1.1). This was part of a study to monitor the children's reactions to different appearances of the robot, cf. Ferrara and Hill's study (1980) where children with autism play with different non-robotic toys. The comparison of these two experimental conditions is beyond the scope of this paper and will be discussed in a separate publication.

The trials were designed to be unconstrained, with minimal structure, to allow the children to have the greatest degree of freedom. In the trials that are reported in this paper, the robot has been programmed to operate in a very basic mode as a 'dancing toy', i.e. the robot executed a preprogrammed sequence of movements. In this mode it moved its arms, legs and head to the beat of pre-recorded music. We used children's rhymes, following the teacher's advice about the children's preference.

4.4 The children

The data presented in this paper is part of a larger study (Robins et al., 2004) involving four children, age 5–10 years. All children have been diagnosed with autism, according to their medical records. Each child participated in as many trials as was possible during a period of 12 weeks. On average, each child participated in nine trials, whereby each trials lasted on average 3 minutes. In total, the study provided 115 minutes of data in the form of video footage. However this paper reports on only three specific trials with three different children. The children are:

Child A – Age 5, in the Reception class. A uses only two or three words but is beginning to communicate using the Picture Exchange Communication System (PECS).

Child B – Age 6, in year one. B has some limited verbal expression which he uses to express some needs, likes and dislikes. He understands simple directions associated with routines.

Figure 1.1. The robot has two different appearances used in the trials (the centre figure shows the 'undressed' version revealing the robotic parts that control its movement.)

Child C – Age 10, in year 5. C has autism combined with severe learning difficulties. He has no verbal language and uses symbols and signs to make choices and to express basic needs. He will generally have a go at whatever task he is presented with unless he is feeling unwell when his behaviour deteriorates.

Once a year the school assesses the pupils' performance using the Qualification and Curriculum Authority's (QCA) P-scale method (QCA, 2004). It is important to view the children's behaviour during the trials in the context of their personal development level which was assessed by their teacher six months prior to the trials.

According to the assessment of their personal and social development level, in the area of interacting and working with others, child A was assessed at a level where he engages in solitary play or work and shows little interest in the activities of those around him. Children B and C were assessed at a level where they might take part in work/play with one other person and take turns in simple activities with adult support. On the subject of attention, A and B have been assessed at a level where they pay rigid attention to their own choice of activity, and are highly distractable in activities or tasks led by others. C has been assessed at a level where he can attend to an adult directed activity but requires one to one support to maintain his attention.

4.5 Trial procedures

Before each trial, the robot was placed on a table ready to start with a click of a button from the laptop. The investigator was sitting next to this table operating the laptop when necessary.

The children were brought to the room by their carer, one at a time. Each trial lasted as long as the child was comfortable with staying in the room. The trials stopped when the child indicated that he wanted to leave the room or if he became bored after spending three minutes in the room. During the trials the investigator did not initiate communication or interaction with the child, but did respond when addressed by the child.

5. The data transcript

5.1 How the data has been selected

During the analysis of the video recordings of this set of trials we noticed several occasions when the children interacted with the adults in the room (i.e. their carer, and the investigator). Sometimes this occurred in relation to the robot, when the robot acted as a mediator or an object of shared attention, and at other times these interactions were not robot related. We have selected from a small proportion of the overall data in which joint attention issues become relevant and where the children reveal communicative competencies. Note, CA is a very time consuming technique that requires highly specialist skills of the coder, and can thus realistically only be applied to a small corpus of the total video data collected. Certain highly 'meaningful' sequences were identified and analysed in more detail using CA, in order to focus in depth on specific interactional competencies, i.e. joint attention. To understand subtle details of the events that take place in such interactions requires attention to the autistic child's activities in their interactional context, for this purpose single episodes were considered sufficient.

5.2 How the transcript is organised

The transcripts are a simplified version of the vocal and non-vocal activities of the participants A (an autistic child), Exp. (the experimenter) and the robot. A teacher is also present in the room but remains silent and off camera throughout the interaction. The transcript is an amended form of Jefferson's (1984) conventions (details of which are available at (CA Tutorial, 2004)). The video footage that we analysed was carefully selected from 115 minutes of video data to best illustrate instances of joint attention.

To read the transcript first note that moving from left to right and from one line number to the one below provides the temporal sequence in which the activities occurred. Because so many activities might occur at any one time sometimes several lines are taken up to note what occurred at that precise point in the sequence. All vocal utterances are comprised of bold letters which capture the sound produced (without recourse to phonetic transcription). Where these occur simultaneously the left square bracket symbol '[' is used to denote the onset of the overlap. Where there is doubt about the vocalisation produced it is placed in single round brackets. Any explicit description of behaviour is placed in double round brackets.

A large number of arrows are used in the transcript to pinpoint the moment of onset or cessation (sometimes both) of a given action. This moment is measured against any vocalisation (if present) or the timed interval between vocalisations (measured in tenths of a second) indicated by hyphens. Hence the arrows will point to the precise moment during an articulation of a sound at which the indicated event occurred or the precise moment in time after the end of the last vocalisation.

In this way the vocalisations, and intervals between them, provide a time-line on which all of the interactional activity recorded is mapped and which provides the reader with a sense of the sequential arrangement of the interaction. Additionally photo stills from the video are indicated by means of the following composite symbol: #1↓ the number indicating the image captured at the precise moment indicated by the arrow.

5.3 The physical surroundings

The Child (A) is sitting on the experimenter's (Exp.) lap (see image 1) who is crouched on the floor facing toward the robot (which is placed on a table directly in front of them). The robot moves its arms hands and legs as indicated but between lines 1 and 11 the robot's left leg does not move but is instead fixed in a slightly protruding position relative to the other leg (due to a temporary technical fault).

6. Analytic observations

The following analytic observations focus on body movements and vocal expressions. As an anecdotal remark, all children showed laughing, smiling, giggling etc. during the trials which seems to indicate enjoyment. This is important to our general aim to create an enjoyable environment where children with autism can play with robots. However, the affective nature of the interactions was not a focus of our study and was therefore not evaluated in detail.

6.1 Conspicuous noticing

In this extract, A demonstrates visually in a variety of ways a concern with or interest in the robot's temporarily static left leg. In line 1 A leans in to the left leg momentarily, in line 2 (image 1) of the transcript A touches the robot's left foot. This is followed by a push against the foot (line 3) and A's leaning in towards the robot (line 3) and eventual near contact between A's face and the robot's left foot (lines 5 to 8, image 2). These activities on the part of A can possibly be interpreted as simple expressions of inner cognitive concerns (such as his interest in or awareness of a problem with the robot's left leg movement) however they are also *made available* both for our inspection analysing the data and for his co-participant Exp. who is gazing from behind.

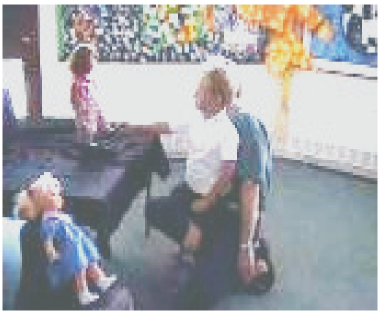

Image 1.

Image 2.

Note that the child's attention to the robot's leg takes various forms; from the relatively indirect leaning in towards it in line 1, to the manual contact with and manipulation of it in lines 2 and 3, through to a still more overt near face contact with it in lines 5 to 8.

These activities seem to involve an escalation of intensity prior to Exp.' s overt orientation to the robot's leg in line 8 after which A stands up whilst producing a vocalisation oriented to Exp. Tentatively there are grounds for understanding A as producing *increasingly obvious orientations* to the robot's left leg until the time that Exp. displays an orientation to the robot's leg himself. That is Exp. is producing visual scrutiny of the target of A's body orientation (Goodwin, 2000). At this point once a possible instance of joint attention has been accomplished A no longer escalates the intensity of his attention to the leg but instead orientates to Exp.

If the child's behaviour were an endeavour to achieve joint attention without lexical resources then the use of increasingly overt orientations to the

Data transcript – lines 1-3:

((robot moves left arm out and back))
↓ ↓
1 A [**aah aah ah ah ah ah** ((melodically))
T__ ((gaze at T))R>_ ((gaze at Robot's left foot until line 10))
↑((head rotating)) ↑ ↑((leans in towards robot's left foot and back))
Exp. [(**huh huh huh**)
((face obscured)) ↑A_>((Exp. gazing at A from behind until line 2, 0.5))
((robot's right leg moves out and back))
#1↓ ↓ ↓
2 (- - - - - - - - - **1**- - - - - - - - - **2** - - - - - - - - - **3** - - - - - - - - - **4)**
A ↑ ↑ ((leans back))
↑ ↑
((A flicks right leg out and back))
↑ ((right hand raised towards robot))
↑>((touches robot's left foot
until line 3, 6.4))
Exp. ↑((Exp.'s face obscured from view until line 3)) ↑
((leans back))
↓((robot's left foot still
slightly protruding))
((robot's head moves to left and back))↓ ↓
3 (- - - - - - - - - **5** - - - - - - - - - **6** - - - - - - - - - **7** - - - - - - - - - **8)**
A ↑>((pushes robots left foot))↑((releases robot's left foot))
↑((leans back retracts arm))
↑((raises left arm))
↑((leans forwards
towards table))
Exp. ↑((face no longer obscured))
↑A/R> ((gazing at A & R)) ↑ ↑ ((gazes at A's left hand))
↑ ((raises left arm)) ↑((rotates head towards R))
↑((gazes at A's right hand
/robot's foot))
↑((gazes down))
↑((head movement and gaze follows A's left hand movement towards the table))
↑((rotates head towards the direction of A's hands/R's feet))

<u>Data transcript – lines 5 -8:</u>

5 Exp. (°**which way** °) ((° **three syllables** °))

↑((head leans in closer to A))

A ↑(face low on the table near to robot's left foot))

↑ ((moves closer to robot's left foot))

↓#2

((robot rotates head right and then back to starting position))

↓ ↓

6 (- - - - - - - - - **1** - - - - - - -)

A ↑((face almost touching robot's left foot))

Exp. ↑((glances slightly up in direction of robot

A within likely field of view))

↑((starts to raise right hand))

↓((robot moves left hand up))

7 Exp. **h<u>E</u>y** >**wh<u>a</u>t you**↑**<u>do</u>ing** <

↑A>((gaze at A>))

↑A>((gaze down at A>))

↑((right hand movement towards A))

↓((robot moves left hand down))

((robot raises then lowers right hand))

↓ ↓ ↓((raises right leg))

8 (- - - - - - - - - **1** - - - - - - - - - **2** - - - - - - - - - **3** - - - - - - -)

Exp. ↑((leans to his right))

↑R/A((gaze at robot's left foot/ A's face))

((Exp.'s gaze follows A's head as he starts to get up))↑

A ↑((starts to get up))

↑

((standing facing robot))

target (which are only dropped after the co-participants attention has been secured and which upon securing is followed by mutual gaze with the co-participant) would be a successful strategy. That is, A has used his body as a 'visible locus' for displaying 'intentional orientation through gaze and gesture'— a skill found in the interaction of competent adult participants (Goodwin, 2000).

6.2 Organisation of vocalisations and gaze

This section examines the organisation of vocalisations and gaze of the child and the experimenter.

Data transcript – lines 9-11:

9 A (**n:y A:rhk**)
↑((rotates around towards Exp.))
↓#3
↓((robot right leg lowered to initial position))

10 (- - - - - - - -)
A ↑ Exp.>((gaze at Exp.'s face until line 11))
Exp. ↑ A>((gaze at A's face until line 13)
↓((robot's left leg starts to move -previously being static))

11 A [(**nyim:a**))
↑Exp.__ ((gaze at Exp.))
↑((starts to look down - but able to monitor Exp.'s face and his own feet))
Exp. [(°**good** °)
↑ A>((continues to gaze at A's face)

In lines 9 and 11 A produces vocalisations. Whilst these vocalisations cannot readily be decoded into recogniseable words (by those unfamiliar to A's talk at least) they do show certain interesting properties in the organisation of A's body orientation and gaze, coinciding with their production. In line 9 A's vocalisation starts whilst standing facing the robot — but as it begins A rotates away from the robot and towards the adult (the experimenter- Exp.). This very action could be understood as referencing the first articulation to a particular physical space (the robot) by virtue of its onset whilst gaze is at the robot, Goodwin & Goodwin (2000). Furthermore the onset of A's rotation treats the vocalisation as designed for Exp. (as a recipient) as A rotates to Exp. whilst the vocal sound is produced. A produces his second and final articulation in line 11 having secured mutual gaze (gaze at each other's eye area) with his adult co-participant (Exp.).

Note, that an interval of 0.8 seconds occurs between the two vocalisations and that A produces the second vocalisation very soon after mutual gaze is established. In this way A is displaying a design in the timing of his second vocalisation such that it occurs only after Exp.' s gaze at A has been secured (image 3, line 10). This accomplishes some important interactional work, in that securing mutual gaze confirms that Exp. is an intended recipient of the vocalisation, (Heath, 1984). This is particularly important given that the earlier vocalisation (neccessarily) involved A's gaze being directed away from Exp. and at the robot. Furthermore, the placement of the gaze is such that it occurs with the ending of A's vocalisations — a transition point when speaking participants routinely gaze at their co-participants (Heath, 1984).

Image 3.

By bringing his gaze to Exp. at this precise moment A designedly selects Exp. as the intended recipient of his vocalisation, is able to monitor Exp.' s responses to his vocalisations, and makes his own activities, including the cessation of speakership available to Exp.

6.3 Establishing mutual orientation to and through gesture

In line 10 (cf. image 3), as noted above, A establishes mutual gaze. After this is achieved A starts to gaze down (initially towards the end of line 11 and more markedly in line 12, image 4, and especially line 13, image 5). The placement of A's gaze downwards after establishing mutual gaze provides an example of A

Data transcript lines 12-13:

↓#4

12 Exp. >° **yes** °<

↑ A>((continues to gaze at A's face))

A ↑((continues to look down))

↓#5

↓#6 ↓#7

↓((robot's head rotates to the left))

13 (- - - - - - - - - **1** - - - - - -)

A ↑((starts to flick right leg out))

↑((gazes down very conspicuously at leg -

still able to monitor Exp.))

↑((starts to gaze up at Exp.))

↑Exp.>((gazing directly at Exp.))

Exp. ↑((gazes down in the direction of A's leg))

↑((gazes more directly at A's leg))

↑A>((gazing directly at A's foot))

designing his actions for his co-participant Exp. such that he can follow A's gaze direction. That is, in endeavouring to design our actions such that a co-participant gazes where we are gazing, it is particularly helpful to achieve mutual gaze with that co-participant and then proceed to direct our gaze to the referent we wish our co-participant to gaze at.

Image 4.

Image 5.

After achieving mutual gaze (line 10, image 3) and having started to direct his gaze downwards (line 12 image 4) A produces a leg flicking movement (line 13 image 5). It can be noted that A flicks his right leg whilst it is the robot's left leg which he had paid conspicuously close attention to and which had been temporarily motionless — however this may be accounted for in terms of the mirror arrangement of the experiment (the child's right leg corresponds to/mirrors the robot's left leg when the child is facing the robot). More important for our current considerations is the fact that A does not even start to produce the leg movement until after he has both achieved mutual gaze and started to gaze down slightly towards his leg. That is, rather than being produced without regard for Exp.' s orientations, A designedly places his leg movement to occur after activities which enable Exp. to visual orientate to it. Furthermore, A's gaze remains at his leg until he has secured Exp.' s overt orientation to it (line 13, image 7) at which point A gazes at the face of Exp.

Image 6.

Image 7.

In this way A has designed his actions to maximise Exp.' s opportunities for joint attention to A's leg movement. This is made still more possible by the size and spatial placement of A's leg movement — which is large and as far as possible made available for Exp.' s visual scrutiny. Thus, A's leg movement is a gesture that serves as a skilful means by which interactants get their recipients to visually orientate to their gestures (Goodwin, 2003a). Furthermore, A produces a still more marked visual orientation to his own gesture (line 13 image 5) which cannot readily be dismissed as him merely being interested in looking at his own leg movement. The placement of A's pronounced visual orientation and its overt production make available to Exp. that A is gazing at his leg and provide a means of securing visual joint attention towards A's leg. This joint attention is successfully accomplished in line 14 image 6 at which point Exp. begins to gaze down in the direction of A's leg, and line 14 image 7 where Exp. gazes more directly at A's leg. In this way the participants themselves display the work that each others actions have accomplished. Exp.' s orientations to the leg movement of A display Exp.' s treatment of the sequence of body, gaze and leg movement that A has executed. Visual joint attention has been achieved in line 13 image 6. A careful analysis of the prior sequence enables us to see the design features on the part of A that have enabled this to be accomplished.

In order to further understand A's use of gaze to secure joint attention it is worth considering some comparative data taken from an interaction between typically developing elementary school children (Figure 7.1 below). Whilst the data involves a different physical setting with different participants a *similar gestural issue* is at stake in the segment analysed here. That is Carla (LEFT) in line 6 produces a foot gesture that carries important interactional meaning. Whilst Carla's earlier hand gesture was clearly placed in the line of vision of Diana (RIGHT, line 4) the foot gesture (despite Diana's downward gaze) is not. Thus as Carla produces her foot stomping gesture she gazes at this gesture (which is followed by Diana's gaze in the direction of the foot movement in line 6) orientating to it as elaborating certain meanings. Goodwin (2003b) notes that gazing at gestures in this way means that they "help locate, not only for analysts, but also for participants, a class of gestures that are clearly built to be communicative" (p. 15).

Similar work is at hand in the gaze of A toward the foot movement that he produces. A's feet were in movement, but not gazed at, as he rotated to face Exp. — the shift of gaze to his moving foot occurs as that foot is moved to convey important meaning (by forming a kicking gesture) — the very gaze shift itself underscoring the communicative import of the foot movement. A's gaze shift to his foot gesture can be seen as skilfully highlighting the communicative import and directing the recipient's attention towards communicative gestures outside of their immediate visual focus. A is thus doing what competent communicators (both adults and children) can be found to do across a number of quite different external contexts, i.e. he orientates to those movements that are designed to be communicative by either placing them in the recipient's line of vision or directing the recipient's attention to them by gazing at them (Goodwin 2003a, 2003b; Streeck, 1993).

6.4 Following the gaze of others

The above analysis has explored how an autistic child can initiate joint attention in a manner which attends to the immediate interactional circumstances they are confronted with. Thus the child was found to move their gaze to their own

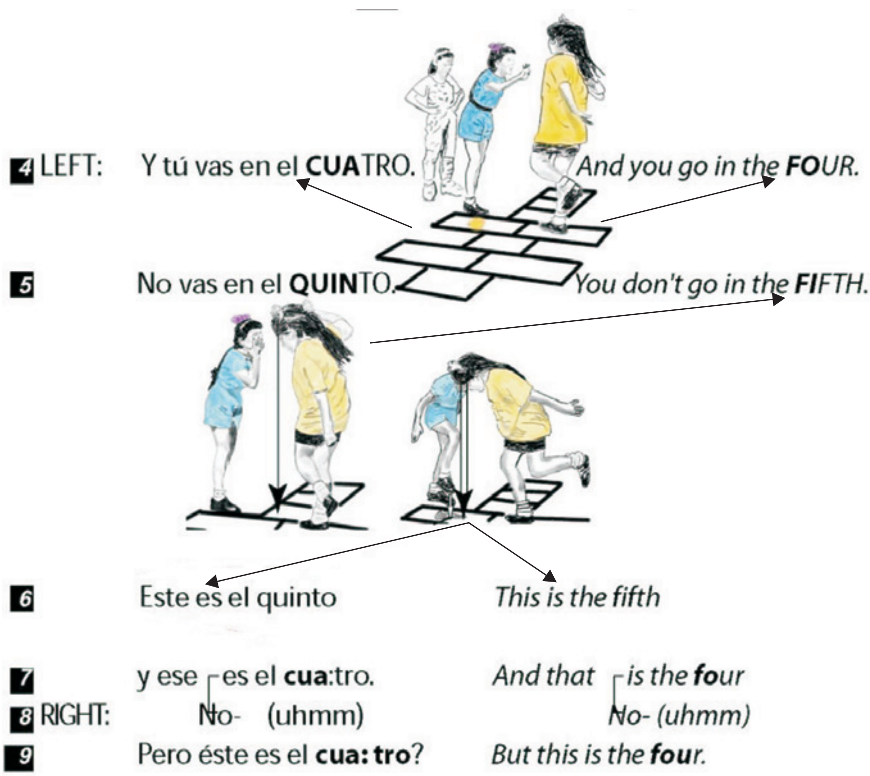

Figure 7.1. Interaction between non-autistic children (reproduced transcript[7]), drawings based on photos of real events.

(communicative) leg gesture in a specific environment in which it could not be assumed that the adult recipient was already noticing it. Whilst space precludes a formal analysis the data below briefly illustrates how children B and C are found to respond to joint attention activity on the part of the adult. In particular we see examples of the children appropriately following the adult's gaze and pointing towards the robot.

Child B:

Image 8.

Image 9.

Images 8 and 9 show that B moves from scrutiny of the adult (who is gazing at B) to following the adult's gaze and pointing, by directing his gaze and body orientation towards the robot.

Image 10.

Image 11.

Images 10 and 11 show B developing his attention to the robot by reaching out to touch it. It can be noted that B's right hand begins to move to touch the robot as the robot lowers its arms. This action on the part of the child may therefore be responsive not only to the gaze direction and pointing of the adult but also to the unfolding activity of the robot.

Child C:

The images below illustrate C's orientation to the gaze and pointing activity of the experimentor (Exp.) as well as what might be understood as his own attempt to initiate further scrutiny of the robot through pulling Exp. towards the robot.

Image 12.

Image 13.

Image 14.

In images 12, 13 and 14, C redirects his eye gaze from the laptop screen to the robot. This movement in C's visual attention is responsive to the gaze and pointing activity on the part of the experimenter (Exp.). Note that image 14 captures C stepping in closer to the robot and pulling Exp. towards him — this pulling activity could be understood as a means of initiating movement on the part of Exp. towards an object of C's scrutiny. This movement coincides with arm movement activity on the part of the robot and can be understood as a way in which C seeks to initiate heightened levels of joint attention (on the part of Exp. towards the currently moving robot).

Image 15.

Image 16.

Image 17.

Image 15 indicates that C's gaze remains on the robot rather than merely following Exp.' s hand itself. That is, C orientates to (or responds to) the pointing and gaze of Exp. as indicating an object of joint attention other than Exp.' s hand itself, namely the robot. C's gaze stays with the robot during a very brief glance by Exp. from the robot to the laptop screen and back, which occurs in between images 15 and 16. By image 16 however, C does follow Exp.' s gaze direction by gazing at the object of scrutiny that Exp.' s gaze has now selected — the laptop screen. It can be noted that this re-orientation in image 16 occurs during a phase in which the robot is relatively stationary and hence produces fewer behaviours to illicit scrutiny on the part of both Exp. and C.

Image 18.

Image 19.

Image 20.

Images 17 and 18 show another instance of C appropriately following the gaze and pointing behaviour of Exp. Exp.' s pointing occurs after both C's stepping back away from the robot and the robot raising its left arm. C again follows the pointing and gaze direction of Exp. by re-orientating to the robot. Image 18 is again suggestive of renewed scrutiny which occurs with, and might be responsive to, the robot's movement of its left arm. In image 19 C brings his gaze to Exp. achieving mutual gaze before stepping away from the scene smiling and moving his arms (possibly in response to the robot's arm movement) as shown in image 20.

7. Discussion and outlook

Our analysis has identified skilful actions on the part of children with autism who demonstrated in various ways an orientation to their co-participant: *shaping* their vocal and non-vocal actions (talk, body movement, gaze and gesture) during the interaction, in light of the actions of the other participants (the robot and the experimenter), or *projecting* that they were about to do so. Importantly, the results of this investigation highlight that a robot can serve as a 'social mediator', an object and focus of attention and joint attention, that children with autism use to communicate with other people.

Although previous literature has indicated joint attention behaviour in children with autism, our analysis revealed subtle details and qualities of joint attention skills in children with autism. Thus, in many respects it is the children who emerged particularly impressively in the interactions that we analysed, they exhibited a capacity for recipient design and used their joint attention skills to do what all skilful interactants do.

First, child A not only attended to the robot's (temporarily) dysfunctional left leg but this attention was done in an overt manner (leaning obviously in next to the faulty leg). This could potentially be understood as designed such that the attention to the leg is available for his adult co-participant to witness and engage with. Whether this interpretation is taken or not, it was seen that this body orientation did get adult attention to the region of the robot's left foot and having done so A then rotated towards the adult. Furthermore, the conspicuous attention to the robot might be understandable as being built upon the subsequent vocalisations, gaze and gesture activities of A — that is they provide a point of reference against which any subsequent actions can potentially be understood. Second, A produced vocalisations, which whilst not recogniseable to the researchers as words, were treated by A with some concern for recipient design. That is, A rotated towards the experimenter in the production of the first vocalisation achieving mutual gaze immediately before and during the production of the final vocalisation. Non-communicative noises and outlouds are distinguishable by their very lack of such orientation to recipients. Third, A not only produced a gesture which appeared to have communicative potential but its performance and placement are strongly suggestive of careful recipient design. Its performance was such that it was made available visually for A's co-participant both through its size and duration and through the placement of A's body with regards to the experimenter's visual orientation. Its sequential placement was such that its occurrance was precipitated by A achieving mutual gaze with the experimenter. Both the gesture performance itself, and A's further demonstrable scrutiny of it could be seen as designed to secure (and securing) the experimenter's visual orientation to the continuing performance of the gesture. Additionally, in exploring the interaction of children B and C, it was found that the children moved their gaze to scrutinise what the adult gazed and pointed at. The photo stills further indicated that the children followed the point and gaze of the adult to locate the relevant object for joint attention (e.g. the robot). Once this attention was given to the robot the children were found to develop additional activities which can be interpreted as responsive to the movement of the robot — such as touching the robot in the case of B, and possibly the arm movement at the end in the case of C. We presented the data in the form of transcripts and photo stills in order to invite the readers of this article to evaluate the claims made, and to possibly propose alternative interpretations. We hope that our work can thus contribute to the lively debate on trying to understand the nature of social behaviour and communication.

In these fragments of data presented, the children with autism have displayed some impressive recipient design skills where the robot served as a salient object mediating joint attention with an adult. Note, it is at present unclear whether this behaviour was caused by, and therefore attributable to, the robot; other objects (e.g. toys widely used in assessments of children's social communication skills, such as mechanical toys, ballons or bubbles etc.) might possibly serve the same role. However, our previous research suggests that the robot's capacity for autonomous movement might play an important role. In (Werry, 2003) a comparative study is presented which compared the behaviour of children with autism towards a mobile, autonomous robot with a non-mobile, passive toy truck of the same size. Results show that the children directed statistically significantly more eye gaze and attention towards the robot. The robot's autonomy, and the fact that it never reproduces exactly the same behaviour but rather variations of behaviours might have played a role in these results. Further research might shed more light on why and how a robot provides an interesting focus of attention for children with autism.

Whilst the data does not allow us to speculate about whether such skills might or might not have occured without a robot present, we can note that in this instance the skilful interaction on the part of the children occurred not just in the presence of a robot but was specifically concerned with features of the robot's *behaviour*. The autonomous and predictable pattern of the robot's moving arms, legs and head caused A, for example, to notice the temporarily faulty left leg. Similarly, the robot's arm movement attracted B's and C's attention. In all these cases the robot provided an environment for noticing, on the part of the autistic children, and it served as a salient reference point against which certain actions on the part of the child (and adult) might be understood. These examples support our previous interpretation that a robot might act as a social mediator (Werry et al., 2001), mediating interactions betweeen an autistic child and other people.

Note, for the purpose of our project it is not central to show that the robot is better than other objects at mediating joint attention. Using a robot with children with autism has potentially many educational, therapeutic, as well as practical benefits that motivate our research. Different from other objects, a robot can be programmed and thus potentially fulfill a number of roles in the context of autism therapy and education. For example, it can potentially learn from the interactions, and adapt to individual children, a functionality that cannot be adopted by other non-robotic toys (Dautenhahn & Werry, in press). Also, since it can be used in an autonomous mode it does not necessarily require an adult to operate it constantly. Thus, while a child interacts safely with a robot the carer or parent present could be relieved temporarily from often demanding one-to-one interactions, e.g. allowing the adult to evaluate the interactions from a third person perspective. Other advantages and disadvantages are considered in (Dautenhahn & Werry, in press).

As discussed earlier (Section 2), the emphasis of our work is on investigating the development of robots' interactive skills (using Artificial Intelligence and robotics techniques) to potentially make a contribution to the therapy or education of children with autism. At present, the specific nature of autism is not the major focus of our efforts, this paper could just give one particular example of work in this direction. If pursued in more detail, further extensive trials as well as quantitative and qualitative evaluations would be required. This paper highlighted the benefits of a CA approach which suited our particular research interests in this study. However, for different research questions a variety of other approaches can be considered. Last but not least, comparisons between different types of robotic and non-robotic toys could point out specific characteristics in the robot's appearance and/or behaviour that are particularly successful in mediating communicative competencies in children with autism.

To conclude, interactions with robotic 'toys' can serve several useful functions: a) as we emphasized in our previous work, there is some indication that robots can encourage imitative and turn-taking games in children with autism, potentially leading to benefits in the education and therapy of children with autism (e.g. Robins et al., 2004; Dautenhahn & Werry, in press), and b) as shown in this paper, robots can provide an enjoyable focus of (joint) attention that can reveal details of communicative and social competencies of children with autism, a context that might potentially make a contribution to autism research since it highlights certain aspects on the specific nature of autism. Our long-term vision in terms of how robotic toys for children with autism can be used is not to replace human interaction with interactions with robots. On the contrary, the examples of interactions discussed in this paper pointed out how human contact (the experimenter) provides meaning and significance to otherwise mechanical interactions (with a robot). This vision is in line with research into a new generation of social robots that are integrated in society, performing different roles in our lives, empowering rather than constraining people (Dautenhahn et al., 2002; Dautenhahn, 2002).

Notes

* We are grateful to the teaching staff, parents, and children at Bentfield Primary School. Our special thanks go to the headteacher Mr. Draper for his continued support. We would like to thank the anonymous reviewers for very constructive comments that helped us to improve a previous version of this paper.

1. It is known that from birth imitation plays a critical role in the development of social cognition and communication skills. Some researchers show that children with autism are able to engage in immediate imitation of familiar actions (Hammes & Langdel, 1981). However, other research suggests autism-specific impairments in imitation (Rogers & Pennington, 1991; Meltzof & Gopnik, 1993). Nadel et al. (1999) found significant correlation between imitation and positive social behaviour, and indicated that imitation is a good predictor of social capacities in children with autism. It was also found that children with autism improve their social responsiveness when they are being imitated (Dawson & Adams, 1984; Tiegerman & Primavera, 1981; Nadel et al., 1999). A recent study by Field et al. (2001) shows that an adult's imitations of the behaviour of children with autism increases social behaviour in the children. Behaviours evaluated in this study included e.g. looking, vocalizing, touching the adult, being close the adult, or engagement in reciprocal play.

2. Conversation analytic research does not count the frequency of occurrence of any one instance of behaviour. One reason for this is that the same isolated behaviour (such as child gazing at adult) can be understood as accomplishing quite distinct actions depending on the precise location of the behaviour. For example a child gazing at an adult in silence after the adult has asked a question constitutes a different activity than a child gazing at an adult who is looking elsewhere. Attempting to count the frequency of the child gazing at the adult across a corpus of data may run the risk of underestimating the variation in the interactional environments in which such behaviour occurs and therefore failing to notice the very different actions that such behaviour might accomplish. Likewise considerations of what might be 'typical' or 'representative' behaviour based on an inspection of isolated behaviours alone may lead to a segregation of behaviour and the precise interactional environment in which it occurs. From a conversation analytic perspective behaviour and interactional context cannot be meaningfully separated as what the behaviour does or accomplishes depends upon its interactional environment. These considerations mean that the current paper does not refer to frequencies of behaviour nor to a quantitative understanding of 'typical' behaviour across the data corpus. Instead the interactional accomplishments

revealed demonstrate what the children are capable of in responding to the demands of the highly specific interactional environment in which they find themselves. Issues regarding quantification in interactional research are discussed in some detail in Schegloff (1993).

3. Rather than developing an alternative *form of analysis* for interaction Heath & Hindmarsch argue that ethnomethodology and conversation analysis provide the "appropriate analytic orientation" (p. 27) for investigating *the topic* of interaction. Their particular approach demonstrates the ways in which conversation analytic work can usefully incorporate consideration of material context not by a priori assumptions regarding its importance but instead by a careful investigation of how participants themselves treat the phenomena.

4. As we explained above, the emphasis of conversation analysis is on a detailed examination of how co-participants in an interaction collaboratively accomplish sequences of action — that is how they both respond to and shape the vocal and non-vocal actions of each other. From this perspective it is problematic to specify in advance of a careful analysis precisely what sequences of behaviour constitute 'skilful' interaction — as the 'skilfulness' may depend not so much on the isolated enactment of a particular sequence of action, but on the orientation of these actions to the precise moment by moment activities of the child's co-participant. Thus a conversation analytic framework considers all interactional behaviours, including joint attention, as necessarily collaborative or co-constructed between all participants who are present. This framework suggests that one cannot simply focus on the child's behaviour without taking into account how it orientates to and shapes the behaviour of co-present others (such as the experimenter). If the experimenter's behaviour follows a pre-specified script (cf. Carpenter *et al*, 2002) then we can no longer examine the activities children might undertake to elicit certain vocal or non-vocal actions on the part of the experimenter because no account is taken of the experimenter's response to actions undertaken by the child. Furthermore in any experimental situation that attempts to explore interaction the child's own (uncontrolled) behaviour (such as where they are gazing) determines the context against which any action or non-action on the part of the experimenter occurs. This prior activity of the child within an experimental trial shapes the specific interactional meaning of the experimenter's own behaviour thereby attenuating the possibility of precise replication (even if the experimenter performs the same action the child's own activities such as prior gaze direction may change the interactional meaning of that action). Alternatively if the trials to be compared are unscripted (for example comparing autistic and non-autistic children playing with a robot) then the range of interactional sequences that emerge will be vast and it is likely that any attempt to compare child behaviour between trails will be comparing very different sequences of interaction despite the global context (of child, experimenter, room and objects) being the same. It is for these reasons that conversation analysis, rather than replicating external conditions, draws points of comparison with related *interactional* sequences.

5. Robotic toys for typically developing children can easily build on the natural human tendency to anthropomorphise, i.e. to treat a robotic dog pretending the robot is an animal (Dautenhahn, 1997), while it is less clear that this strategy will succeed with children with autism, see discussion in (Dautenhahn & Werry, in press).

6. Cf. (Dautenhahn and Werry, in press) for an in depth discussion of the motivation and background of the Aurora project.

7. The transcript is reproduced following the kind permission of Professors Chuck and Candy Goodwin to whom the authors are indebted for their generosity with this data which is referred to in Goodwin (2000a).

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